sense generally supposed; it is rather a compound of the visceral rami of the anterior spinal nerves, and of the remnants of the brain-ganglia and lateral cords of the nervous system of invertebrata, than of several metameric nerves." Secondly, "that the visceral part of the vagus of fishes includes the branchial nerves, and has arisen from a coalescence of the visceral rami of the anterior spinal nerve segments, the corresponding motor and sensory somatic branches of which have remained separate." Thirdly, "that the ganglia of the cranial nerves (5th, 7th, 9th and 10th) are the representatives of the brain lobes of Nemertea, and probably of the cerebral ganglia of Annelida and Arthropoda." Fourthly, "that the ramus lateralis is of extreme ancestral origin, and is equivalent to the lateral strands in the nerve plexus of Nemertea, to the main nervous system of Annelida and Arthropoda, and possibly also to the nerve ring of Coelenterata." Fifthly, "that a study of the vagus nerve throws light on the question of the chordate ancestor, and does not tend to support the views of Dohrn and his school." Sixthly, "that the value of the vagus in deciding the question of the segmentation of the vertebrate head has been much overrated."

F. T.

A Rudimentary Sense Organ.

(1). *Zur Deutung und Entwickelung des Gehirns der Knochenfische.* Rabl-Rückhard. Archiv. f. Anat. u. Physiol. (Anat. Abth.) 1882.
(2). *Untersuchung über das Gehirn der Petromyzonten.* F. Ahlborn. Zeit. f. wiss. Zool. Bd. XXXIX, 1883.
(3). *Ueber die Bedeutung der Zirbeldrüse.* F. Ahlborn. Ibid. Bd. XL, 1884.
(4). *Zur Anatomie u. Entwickelung der Epiphyses bei Amphibien und Reptilien.* H. W. De Graaf. Zool. Anz., March, 1886.
(5). *On the Presence and Structure of the Pineal Eye in Lacertilia.* W. B. Spencer. Quart. Jour. Micr. Sci., October, 1886.
(6). *The Parietal Eye of the Cyclostome Fishes.* J. Beard. Ibid. July, 1888.
(7). *The Pineal Eye in Extinct Vertebrates.* E. D. Cope. Am. Naturalist, October, 1888.
(8). *Recherches sur le développement de l'epiphyse.* P. Franchotte. Archiv de Biologie, Tome VIII, 1888.

Amongst human anatomists there has existed much doubt and consequent diversity of opinion concerning the function of the pineal gland or epiphysis of the brain.

Recently—within the last three years—we have advanced far towards a solution of the problem, by a comparative study of this so-called gland in the different classes of vertebrates.

In 1882 Rabl-Rückhard (1) was the first to throw some light upon the function of the gland. He suggested, from his study of its development in the trout, that the pineal body might represent an eye and was comparable to the paired lateral eyes, but failed to give properly the anatomical structure of this median eye.

Ahlborn (2 and 3) carefully described its structure in the fish Petromyzon in 1883; and in 1884, discussing the nature of the pineal gland, says he comes to the conclusion that it may be regarded as the rudiment of an unpaired eye, and to be compared perhaps to the median eye of the lancelet and of the tunicates.

In 1886 de Graaf (4) first conclusively showed that in one of the lizards (Anguis) the pineal gland is modified into a structure directly comparable to an invertebrate eye. He further showed that in amphibia and reptiles this body arose as a hollow outgrowth of the hind part of the first brain vesicle—thalamencephalon—that this outgrowth became constricted off distally into a hollow sphere, and the proximal portion formed a stalk connecting the sphere or bulb to the brain.

The general attention of naturalists was drawn to the subject by an admirable article of W. Baldwin Spencer in the Quarterly Journal for 1886 (5). He confined his research to an exhaustive study of the eye in the group Lacertilia, and within the same group found all stages of development; in some forms a simple outgrowth—evagination—from the upper wall of the brain, and in others developed into a well defined eye. As to the general form of the epiphysis he says, "The simplest form is seen in Platydactylus, where it has merely the structure of a hollow outgrowth running at right angles to the surface of the thalamencephalon until it reaches the dura mater lining the cranial cavity. In Hatteria, on the other hand, we have a form in which specialization is carried to its farthest extent, with the result that the epiphysis becomes modified into three parts, (1) a proximal part, still hollow, and connected with the brain roof, (2) a median solid pineal stalk serving to connect the former with (3), the distal portion differentiated into an optic cup. These forms may be taken as two extremes, the gap between which is filled up by various modifications."

In his examination of Hatteria he made out the following structures. An absence of pigment in the skin indicates the position of the median eye, and beneath it lies that organ in a foramen between the parietal bones. Beneath the unpigmented skin there is found a layer of connective tissue, which would prevent an image being formed in the eye, and indicates in this particular a considerable amount of degeneration, even in this highly organized structure. He compares the general shape of the eye to a cone with its base towards the surface and the pineal stalk or nerve connected with the apex. The walls of this vesicle are divided into (1) an anterior portion (base of the cone) which forms a lens, and (2) a posterior (sides of cone) which is the sensitive area or retina.

A study of this retina has yielded most interesting results and we cannot do better than quote the author's own words. He says: "The retinal elements are arranged in a manner typical of invertebrates, *i. e.* the rods lie on the inner side bounding the cavity of the optic vesicle, the nerve entering posteriorly and not spreading out in front of the rods. In the same vertebrate animal we thus find eyes developed on both vertebrate and invertebrate types, both being also formed from the modification of the walls of hollow outgrowths of the brain," and, it may be added, both arising from the walls of the embryonic fore-brain, approximating to the same place of origin in the early stages of development. The retina is found to consist of the following structures: "a rod-like layer of bodies enveloped in deep pigment," which rods show a remarkable specialization in the optic axis of the eye. Here they are elongated to twice their ordinary length, and are connected at their proximal ends (outer ends in relation to center of cup) with a group of nucleated cells, which cells are connected with the fibers of the optic or pineal stalk.

The retinal elements to the right and left of the axis are connected at their proximal ends with nucleated bodies, and these in turn send down processes into the pineal stalk. Other interesting structures are described, but for details his figures should be consulted. Longitudinal vertical sections through the head of the lizard show that the eye is connected with the epiphysis of the brain by a solid well-marked stalk—the pineal stalk. The elements of this pineal stalk or nerve have "much the appearance of those found at an early stage in the developing nerve of the paired eyes, that is, they resemble cells which are undergoing a process of elongation so as to form long fibers."

The pineal gland has been found in fishes, amphibians, reptiles, birds and mammals in varying stages of degeneration, reaching its greatest development in reptiles, and is least developed (or most degenerate) in mammals. In some forms, viz. the lizards especially, a foramen is left between the parietal bones. In others even this is obliterated, thus in the amphibian cutting off the bulb from the pineal stalk, and enclosing within the skull in mammals all that remains of the pineal eye.

There is an eye developed in the median line in the Tunicates and in Amphioxus, and since Kowalevsky showed in 1866—and his results have been fully verified—that these two groups of animals must be included in the same great group with the vertebrates, the temptation to homologize this eye with the pineal eye is very strong. And when we further see that in both these groups the median eyes develop from the upper surface of the nerve tube at its anterior end, the resemblance becomes very striking. On the other hand, when we see how easily any epidermal cell becomes specialized to receive light vibrations—so much so that this property is often ascribed as one of the general properties of protoplasm—we must be very cautious before we homologize these structures; especially so when they differ much in details. Mr. Spencer discusses this relation and concludes "that the eye of the larval Tunicates is probably homologous with the pineal eye, and that the eye of Amphioxus may be in no sense homologous."

In the *Quarterly Journal* for July, 1888, Dr. J. Beard (6) has given an account of the structure of the pineal eye as found in the Cyclostome fishes, including the forms Ammocoetes and its adult condition Petromyzon, and Myxine. This very ancient group of fishes was chosen "on account of their exceedingly primitive characters," hoping in this way to get some clue as to the phylogeny of the parietal eye.

He finds the structure strictly comparable to the eye of the higher forms, and in all these forms the pineal bulb is connected by means of a stalk to the brain. Distally the wall of the bulb forms an unpigmented lens, beneath which is a cavity filled with fluid, and the proximal wall forms a retina. The histology of the retina in Petromyzon is one of the most interesting results of his research. With a low power of the microscope it is seen to be made up of three layers: "(1) an inner layer of rods (inner in relation to center of eye), which also contains pigment; following this, (2) a layer of nuclei; and outside this, (3) a granular layer containing a few ganglion cells." The inner layer of rods (1) shows an exceedingly interesting structure, and, to quote his own conclusions, "the end elements are shown to be of two kinds, comparable, it seems to me, to those in

the retina of ordinary eyes. By far the most numerous are the long rods; but in addition, and between the latter, one finds a few cones." Both rods and cones contain nuclei, and are directly continuous with the nucleated cells of the nuclear layer (2). These cells are in turn continuous with the ganglion cells of the outermost layer (3), which send processes into the pineal stalk.

Beard's conclusions as to the method of evolution of the pineal eye are exceedingly interesting, but very hypothetical. He says, "I think the development does show that the parietal eye is a slightly later development than the paired eyes, and that the organ has developed in connection with the paired eyes." He starts with the views of Balfour and others, that the paired eyes once opened dorsally "on the surface of the unclosed neural plate," and as the nerve plate gradually sunk below the outer surface of the body, the "neural plate and eyes got shut in," and at the same time the eyes received light laterally, that is, from the sides of the body, or on the ends of their retinal cells which trail out into the nerves. Beard supposes that at the time of closure of the neural tube, a portion of the primary dorsal light-sensitive area became pinched off, as the median eye, which, as we have seen, would still receive its nerve supply from behind (invertebrate type); that by the involution of the optic cup of the lateral eyes they would receive their nerve supply on the same surface which received the light (vertebrate type).

Prof. Cope (7) has examined the skulls of some extinct vertebrates with reference to the pineal or parietal foramen. Referring to the skulls of two very old fishes, he says: "The structure of the primitive vertebrates strongly indicates the origin of lateral or paired eyes from a single median eye, such as is found in Tunicata." "Among North American extinct reptiles," he believes that Diadectes "relied exclusively on the pineal eye for the sense of sight," while in others in which the parietal foramen is closed, casts of the brain show an extemely large epiphysis, and at the same time in Belodon a communication with the orbit (of the lateral eyes) is established.

The work of P. Franchotte (8) on the epiphysis in Anguis covers about the same ground as that of de Graaf and Spencer on that animal.

Thus all the evidence which has come in points conclusively to the fact that the pineal body or gland developed primarily as a median pineal eye. A study of extinct forms shows a larger parietal foramen than found in existing forms, indicating in some, perhaps, a better developed pineal eye.

A study of living forms indicates an absence of function as an organ of sight, for in none are *nerve fibers* discovered connecting pineal eye with brain, though the nerve stalk is there. All the essentials necessary for sight are shown to have *at one time* existed, but the pineal body must now be relegated to the class of rudimentary organs. T. H. MORGAN.

The Pineal Body (Epiphysis Cerebri) in the Brains of the Walrus and Seals. Sir WILLIAM TURNER. Jour. of Anat. and Phys. Vol. XXII, 1888, pp. 300–303.

In this paper, which was read before the Royal Society of Edinburgh, in December 1887, Sir William Turner makes some interesting statements respecting the appearance, position, and relations of